Computron VM is virtual computer machine, running under Java Runtime Environment (www.java.com) supported by Computron interface, as follows

Computron has two periferals:

- Alphanumeric screen, and
- ODFC Programming Device

Computron Interface and Screen are sufficient for binary programming.

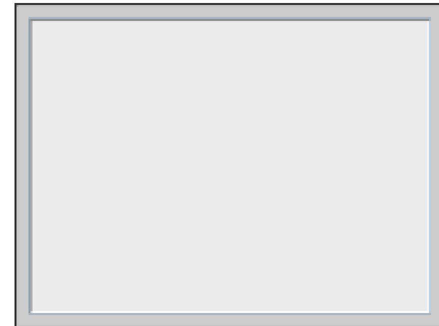
ODFC Programming device is peripheral device for entering data in Octal, Decimal, Floating Point and Character formats, and for loading and saving binary programs.

Assembler Help is useful for storing instructions to memory in octal code, using ODFC device.

ODFC Programming Device

Code	Instr	Attr
00	NOP	
01	BZE	adr
02	JMP	adr
03	JSR	adr
04	RTS	
05	EXIT	
06	INPC	
07	INP	
010	INPR	
011	OUTC	
012	OUT	
013	OUTR	
014	POP	
015	POPR	
016	PUSH	
017	PUSHR	
020	LDA	adr

Assembler Help



Computron Screen

Computron Architecture

is word oriented architecture (1 word=16bits), which consists of Central Processing Unit (**CPU**) and main Memory (**M**).

CPU has four single-word registers

PC	Program Counter
SP	Stack Pointer
A	Accumulator
X	Index Register

and one double-word register

R Real Numbers Register: RH is the higher and RL is the lower word of R.

Computron Memory **M** is the array of 64K, i.e 65536 single-word registers M[0], M[1] … M[177777].

Note: The indices of array M are memory addresses. The lowest address is 0, and the highest address is 65635 (177777 in octal representation). In CPU, a memory register M[PC] is accessed automatically based on the value of an address stored in PC. A real number (in float type representation) is stored in two subsequent registers (cells) of memory, RL at address addr and RH at address addr+1.

Floating point numbers are in this range

-Infinity > -3.4028235E38 ... -1.4E-45 , 0 , 1.4E45 ... 3.4028235E38 < Infinity

RH and RL octal values for a floating point boundaries stored in R, are as follows.

R	RH	RL
- Infinity	177600	000000
-3.4028235E38	177577	177777
-1.4E-45	100000	000001
0	000000	000000
1.4E-45	000000	000001
3.4028235E38	077577	177777
Infinity	077600	000000

Note: Floating-point numbers use the IEEE (Institute of Electrical and Electronics Engineers) format. Single-precision values with float type have 4 bytes, consisting of a sign bit, an 8-bit excess-127 binary exponent, and a 23-bit mantissa. The mantissa represents a number between 1.0 and 2.0. Since the high-order bit of the mantissa is always 1, it is not stored in the number. This representation gives a range of approximately 3.4E–38 to 3.4E+38 for type float.

Computron Instruction Set

Instruction Categories

1. No Operation Instruction
2. Control Flow Instructions
3. Input from keyboard Instructions
4. Output to screen Instructions
5. Stack PUSH and POP Instructions (single and double word)
6. Load accumulator A from memory
7. Load register R from memory
8. Store accumulator A and register R to memory
9. Load/Store index register X and stack pointer SP from/to memory
10. Boolean operations
11. Comparisons of words using register A and double words using register R
12. Arithmetic operations on integer and real numbers

Note: If instruction operational code is at address PC, then attribute (adr or val) of each attributed instruction is at address PC+1, and then adr = M[PC + 1], or val = M[PC + 1].

No Operation Instruction			
Octal Code	Name	Attrib	Operational Semantics
000000	NOP		PC := PC + 1;
No operation			

<table>
<tr><th colspan="4">Control Flow Instructions</th></tr>
<tr><td>Octal Code</td><td>Name</td><td>Attrib</td><td>Operational Semantics</td></tr>
<tr><td>000001</td><td>BZE</td><td>adr</td><td>if (A = 0) then PC := adr else PC := PC + 2;</td></tr>
<tr><td colspan="4">Branch if zero: conditional jump to address adr</td></tr>
<tr><td>Octal Code</td><td>Name</td><td>Attrib</td><td>Operational Semantics</td></tr>
<tr><td>000002</td><td>JMP</td><td>adr</td><td>PC := adr;</td></tr>
<tr><td colspan="4">Non-conditional jump to address adr</td></tr>
<tr><td>Octal Code</td><td>Name</td><td>Attrib</td><td>Operational Semantics</td></tr>
<tr><td>000003</td><td>JSR</td><td>adr</td><td>M[SP] := PC + 2; SP := SP + 1; PC := adr;</td></tr>
<tr><td colspan="4">Jump to subroutine</td></tr>
<tr><td>Octal Code</td><td>Name</td><td>Attrib</td><td>Operational Semantics</td></tr>
<tr><td>000004</td><td>RTS</td><td></td><td>SP := SP – 1; PC := M[SP];</td></tr>
<tr><td colspan="4">Return from subroutine</td></tr>
<tr><td>Octal Code</td><td>Name</td><td>Attrib</td><td>Operational Semantics</td></tr>
<tr><td>000005</td><td>EXIT</td><td></td><td>running_signal := false;</td></tr>
<tr><td colspan="4">Exit – stops machine execution</td></tr>
</table>

Input from keyboard Instructions			
Octal Code	Name	Attrib	Operational Semantics
000006	INPC		A := typed_character_ascii_code(); PC := PC + 1;
Input character from keyboard			
Octal Code	Name	Attrib	Operational Semantics
000007	INP		A := typed_integer_value(); PC := PC + 1;
Input integer from keyboard			
Octal Code	Name	Attrib	Operational Semantics
000010	INPR		R := typed_floating_point_value(); PC := PC + 1;
Input real number from keyboard			

Output to screen Instructions			
Octal Code	Name	Attrib	Operational Semantics
000011	OUTC		display_character_of_code_in (A); PC := PC + 1;
Output character to screen			
Octal Code	Name	Attrib	Operational Semantics
000012	OUT		display_integer_value_in (A); PC := PC + 1;
Output integer to screen			
Octal Code	Name	Attrib	Operational Semantics
000013	OUTR		display_floating_point_value_in (R); PC := PC + 1;
Output real number to screen			

Stack PUSH and POP Instructions (single and double word)			
Octal Code	Name	Attrib	Operational Semantics
000014	POP		SP := SP – 1; A := M[SP]; PC := PC + 1;
Pop word from stack to accumulator A			
Octal Code	Name	Attrib	Operational Semantics
000015	POPR		SP := SP – 2; R := (M[SP], M[SP + 1]); PC := PC + 1;
Pop real number from stack to register R;			
Octal Code	Name	Attrib	Operational Semantics
000016	PUSH		M[SP] := A; SP := SP + 1; PC := PC + 1;
Push word in A on the stack			
Octal Code	Name	Attrib	Operational Semantics
000017	PUSHR		(M[SP], M[SP + 1]) := R; SP := SP + 2; PC := PC + 1;
Push real number in R on the stack			

Load accumulator A from memory			
Octal Code	Name	Attrib	Operational Semantics
000020	LDA	adr	A := M[adr]; PC := PC + 2;
Load value to A from memory cell at address adr			
Octal Code	Name	Attrib	Operational Semantics
000021	LDA’M	val	A := val; PC := PC + 2;
Load value val to A from memory address PC+1 (immediate addressing)			
Octal Code	Name	Attrib	Operational Semantics
000022	LDA’I	adr	A := M[M[adr]]; PC := PC + 2;
Load value to A from memory cell at address M[adr] (indirect addressing)			
Octal Code	Name	Attrib	Operational Semantics
000023	LDA’X	val	A := M[val + X]; PC := PC + 2;
Load value to A from memory cell at address val+X (indexed addressing)			

Load register R from memory			
Octal Code	Name	Attrib	Operational Semantics
000024	LDR	adr	R := (M[adr], M[adr + 1]); PC := PC + 2;
Load value from memory cell at adr to RL, and value from cell at addr+1 to RH			
Octal Code	Name	Attrib	Operational Semantics
000025	LDR’I	adr	R := (M[M[adr]], M[M[adr] + 1]); PC := PC + 2;
Load value from memory cell at M[adr] to RL, and from M[adr] + 1] to RH (indirect addressing)			
Store accumulator A and register R to memory			
Octal Code	Name	Attrib	Operational Semantics
000026	STA	adr	M[adr] := A; PC := PC + 2;
Store value from accumulator A to memory cell at address adr			
Octal Code	Name	Attrib	Operational Semantics
000027	STA’I	adr	M[M[adr]] := A; PC := PC + 2;
Store value from accumulator A to memory cell at address M[adr] (indirect addressing)			
Octal Code	Name	Attrib	Operational Semantics
000030	STR’I	adr	(M[M[adr]], M[M[adr] + 1]) := R; PC := PC + 2;
Load value from RL to cell at address M[adr], and from RH to M[adr] + 1] (indirect addressing)			

Load/Store index register X and stack pointer SP from/to memory			
Octal Code	Name	Attrib	Operational Semantics
000031	LDX	adr	X := M[adr]; PC := PC + 2;
Load from memory to index register X			
Octal Code	Name	Attrib	Operational Semantics
000032	STX	adr	M[adr] := X; PC := PC + 2;
Store from index register X to memory			
Octal Code	Name	Attrib	Operational Semantics
000033	LDS	adr	SP := M[adr]; PC := PC + 2;
Load fro memory to stack pointer SP			
Octal Code	Name	Attrib	Operational Semantics
000034	STS	adr	M[adr] := SP; PC := PC + 2;
Store from stack pointer SP to memory			

Boolean operations			
Octal Code	Name	Attrib	Operational Semantics
000035	OR	adr	if ((A = 0) && (M[adr] = 0)) then A := 0 else A := 1; PC := PC + 2;
Disjunction operation			
Octal Code	Name	Attrib	Operational Semantics
000036	AND	adr	if ((A = 1) && (M[adr] = 1)) then A := 1 else A := 0; PC := PC + 2;
Conjunction operation			
Octal Code	Name	Attrib	Operational Semantics
000037	NOT		if (A = 1) then A := 0 else A := 1; PC := PC + 1;
Negation operation			

Comparisons of words using register A and double words using register R			
Result is stored in A, where false is represented by 0 and true by 1.			
Octal Code	Name	Attrib	Operational Semantics
000040	EQ	adr	if (A = M[adr]) then A := 1 else A := 0; PC := PC + 2;
000041	NE	adr	if (A != M[adr]) then A := 1 else A := 0; PC := PC + 2;
000042	LT	adr	if (int (A) < int (M[adr])) then A := 1 else A := 0; PC := PC + 2;
000043	LE	adr	if (int (A) <= int (M[adr])) A := 1 else A = 0; PC := PC + 2;
000044	GT	adr	if (int (A) > int (M[adr])) A := 1 else A := 0; PC := PC + 2;
000045	GE	adr	if (int (A) >= int (M[adr])) A := 1 else A := 0; PC := PC + 2;
000046	EQR	adr	if (R = (M[adr], M[adr + 1])) then A := 1 else A := 0; PC := PC + 2;
000047	NER	adr	if (R != (M[adr], M[adr + 1])) then A := 1 else A := 0; PC := PC + 2;
000050	LTR	adr	if (R < (M[adr], M[adr + 1])) then A := 1 else A := 0; PC := PC + 2;
000051	LER	adr	if (R <= (M[adr], M[adr + 1])) A := 1 else A := 0; PC := PC + 2;
000052	GTR	adr	if (R > (M[adr], M[adr + 1])) A := 1 else A := 0; PC := PC + 2;
000053	GER	adr	if (R >= (M[adr], M[adr + 1])) then A := 1 else A := 0; PC := PC + 2;

Arithmetic operations on integer and real numbers			
Octal Code	Name	Attrib	Operational Semantics
000054	ADD	adr	A = int (A) + int (M[adr]); PC := PC + 2;
000055	ADD'M	val	A := int(A) + int (val); PC := PC + 2;
000056	SUB	adr	A := int (A) – int (M[adr]); PC = PC + 2;
000057	SUB'M	val	A := int (A) – int (val); PC := PC + 2;
000060	MUL	adr	A := int (A) * int (M[adr]); PC := PC + 2;
000061	DIV	adr	A := int (A) / int (M[adr]); PC := PC + 2;
000062	NEG		A := - int (A); PC := PC + 1;
000063	ADDR	adr	R := R + (M[adr], M[adr + 1]); PC := PC + 2;
000064	SUBR	adr	R := R - (M[adr], M[adr + 1]); PC := PC + 2;
000065	MULR	adr	R := R * (M[adr], M[adr + 1]); PC := PC + 2;
000066	DIVR	adr	R := R / (M[adr], M[adr + 1]); PC := PC + 2;
000067	NEGR		R := - R; PC := PC + 1;

Generating Computron code in C/C++

```
// CVMDataGen.cpp : Defines the entry point for the console application.
//
// Computron Data Generation
//
// ------------------------------------------------------------
// Representative Example, how to generate
//
// 1. operation code of instructions
// 2. (code of) characters, cardinal and octal numbers
// 3. signed integer numbers, and
// 4. real numbers in floating point representation
//
// Output NON EXECUTABLE binary file
// 1. CAN BE LOADED in Computron memory from any initial address
// 2. Binary representation of all data can be checked by incrementing initial address.
// ------------------------------------------------------------

#include "stdafx.h"
#include <stdio.h>
#include <conio.h>
#include <string.h>
```

```
FILE *outstream; // output file stream

char outf[30]; errno_t err; int items;

// -----------------------------------------------------------
// Operation Code OPvalue is a value of enum OP_Codes           -
// converted to unsigned short type representation             -
// -----------------------------------------------------------

enum OP_Code
	{	NOP, BZE, JMP, JSR, RTS, EXIT,
		INPC, INP, INPR, OUTC, OUT, OUTR,
		POP, POPR, PUSH, PUSHR,
		LDA, LDAM, LDAI, LDAX,
		LDR, LDRI, STA,
		STAI, STRI,
		LDX, STX, LDS, STS,
		OR, AND, NOT,
		EQ, NE, LT, LE, GT, GE,
		EQR, NER, LTR, LER, GTR, GER,
		ADD, ADDM, SUB, SUBM,
		MUL, DIV, NEG,
		ADDR, SUBR, MULR, DIVR, NEGR
	};
unsigned short OPvalue;
```

```
// ------------------------------------------------------------
// Character codes Cvalue (0..255),
// Octal numbers Ovalue (\0 .. \177777) and
// Cardinal numbers Uvalue (0 .. 65535)
// are represented by unsigned short type
// ------------------------------------------------------------

// Examples:

unsigned short Cvalue = (unsigned short) 'a';
unsigned short Ovalue = (unsigned short) 0177777;
unsigned short Uvalue = 65535;

// ------------------------------------------------------------
// Signed integers Ivalue (-32768 .. 32767),
// are represented by short type and
// converted to unsigned short type
// ------------------------------------------------------------

unsigned short Ivalue = -32767;
```

```
// ------------------------------------------------------------
// Real Numbers --- represented by Real_Type ---------------------
// ------------------------------------------------------------
// Real_Type is polymorph type for conversion of real value Rvalue
// in Floating Point Format (Rvalue.R) and Double Word Format
// (Rvalue.Dword.RL, Rvalue.Dword.RH). The next equation holds:
//
//              Rvalue = (Rvalue.Dword.RL, Rvalue.Dword.RH)
// ------------------------------------------------------------

typedef union RealRegister {
        float R;
        struct {
                unsigned short RL;
                unsigned short RH;
        } Dword;
} Real_Type;

Real_Type Rvalue;

// Example of two possible ways, how to determine real number
// Rvalue.R = (float) 2.5e31 ;
// or
// Rvalue.Dword.RL=65535; Rvalue.Dword.RH=32767;
```

```
// =============================================================
// Concluding, we need just two procedures for generating Computron code:
//
// void putWord(unsigned short argument);
// and
// void putReal(float argument);
//

void putWord(unsigned short arg)
{
        items = fwrite(&arg, sizeof(short), 1, outstream);
};

void putReal(float arg)
{       Real_Type Rvalue;
        Rvalue.R = arg;
        putWord(Rvalue.Dword.RL);
        putWord(Rvalue.Dword.RH);
};
```

```
int _tmain(int argc, _TCHAR* argv[])
{ char c;
// ==============================================================
// Generating Computron data to output binary file
// 1. Binary file is a file of unsigned short values
// 2. and it can be loaded by ODFC Programming device
// ==============================================================
// Open output file - file of unsigned short values
	printf("\nOutput binary file name: "); scanf("%20s", &outf);
	if( (err = fopen_s( &outstream, outf, "w+b" )) != 0 )
		printf( "Output file %s was not opened\n", outf );
	else {
		// Generating Characters
		putWord('A'); putWord('B'); putWord('Z');
		putWord(012); // newline: (12 octal, 10 decimal)

		// Generating Instruction Operations (without arguments)
		putWord(NOP); putWord(LDAM); putWord(NEGR);

		// Generating Octal Numbers
		putWord(0377); putWord(0177777);

		// Generating Cardinal (Unsigned Decimal) Numbers
		putWord(0); // Cardinal Minimum
		putWord(255); // Cardinal Sample
		putWord(65535); // Cardinal Maximum
```

```
        // Generating Integer Numbers
        putWord(-32768); // Integer Minimum   100000 octal
        putWord(-1);     // Integer Sample    111111 octal
        putWord(0);      // Integer Sample    000000 octal
        putWord(1);      // Integer Sample    000001 octal
        putWord(32767);  // Integers Maximum  011111 octal

        // Generating Real Numbers in Floating Point Representation
        putWord(0000000); putWord(0177600); // -Infinity
        putReal((float) -3.4028235E38); // Minimum Real Number
        putReal((float) -1.4E-45); // Negative Real Number nearest to Zero
        putReal((float) 0.0);
        putReal((float) 1.4E-45); // Positive Real Number nearest to Zero
        putReal((float) 3.4028235E38); // Maximum Real Number
        putWord(0000000); putWord(0077600); // Infinity

        fclose(outstream);
    }
    printf("\nOutput binary file generated\n");
    return 0;
}
```

ODFC Programming Device

ODFC Input Data Formats

Octal: '0' {Octal_Digit}
Decimal: [- |+] Decimal_Digit { Decimal_Digit }
Floating Point: Decimal . [Decimal] [e [+|-] Decimal] | Decimal e [+|-] Decimal
Character-printable: Cx{x}, where C is printable character entered and x is any other character,
non printable: octal or unsigned decimal number, in range 0.. 255

Loading CPU and Memory Registers

After entering a data value, press Enter and then one of accessible Computron registers, as follows.

Data Form	PC	A	SP	X	RH	RL	R	M	M-R	Begin	End
Octal	●	●	●	●	●	●		●		●	●
Decimal	●	●	●	●				●			
Floating Point							●		●		
Character		●						●			

Note: M-R is double word in memory at M[PC,PC+1]

Loading and saving binary programs

1. To load a binary program generated by a compiler or assembler, set starting memory address to value *addrB* using Begin button and press Load button. Binary coded program will be loaded from selected external binary file to Computron memory from *addrB* to *addrB+sizeOfProgram-1 addresses*. After program loading, PC is set to the address *addrB.*

2. To save a binary program stored in Computron memory from *addrB* to *addrE*, set *addrB* using Begin button and *addrE* using End Button. Then press Save Button and enter full name of output file. Binary program will be saved to this file (of total lenghth of *addrE-addrB+1* words.

Note: ODFC Buttons Incr, Decr, and Run have the same effect as those in Computron interface.
However, ODFC Device Load button loads a program (binary data) from external file, while Computron Interface Load loads just one word from memory to a selected register.

Example: Implementing Finite State Automaton on Computron

Assembler form

Label	Instr	Attr	Comment
	ORG	010	// pseudoinstruction origin: beginning octal address 010 is selected.
	JMP	Start	// jump to address Start
Ca:	VAL	'a'	// code of character 'a' (constant) (defined by pseudoinstruction VAL)
Cb:	VAL	'b'	// code of character 'b' (constant)
C#:	VAL	'#'	// code of character '#' (constant)
Var:	WORD	1	// one word is allocated (content is meaningless)
Start:	INPC		// read input symbol (represented by character)
	STA	Var	// store input symbol to Var address
	EQ	Ca	// does input symbol equal to acceptable 'a' ?
	BZE	Err	// if not, input string is Not accepted
Rep:	INPC		// if yes, read next input symbol
	STA	Var	// store input symbol to Var address
	EQ	Cb	// does input symbol equal to acceptable 'b' ?
	BZE	Term	// if not, does it equal to terminating symbol '#' ?
	JMP	Rep	// if yes, 'b' is accepted and next input symbol should be read
Term:	LDA	Var	// reload symbol from Var
	EQ	C#	// does input symbol equal to terminating symbol '#' ?
	BZE	Err	// if not, jump to 'input string is Not accepted'
	LDA'M	'A'	// if yes, input string is accepted, so load indication 'A'
	OUTC		// output 'A' indicating input string is accepted
	EXIT		// stop finite state automaton
Err:	LDA'M	'N'	// since input string is not accepted, load indication 'N'
	OUTC		// output 'N' indicating input string is not accepted
	EXIT		// stop finite state automaton

Binary form (in octal numbers): finiteStateAutomaton.bin

NOTE: File finiteStateAutomaton.bin (36 words) must be loaded from address 010 (octal) and is runnable from address 010 (octal)

address	**value**	**value** (at address+1)	
010:	00002	00016	// jump to Start address
012:	00141		// code of character 'a' (constant)
013:	00142		// code of character 'a' (constant)
014:	00043		// code of character 'a' (constant)
015:	00000		// one word is allocated (content is meaningless)
016:	00006		// read input symbol (represented by character)
017:	00026	00015	// store input symbol to Var address
021:	00040	00012	// does input symbol equal to acceptable 'a' ?
023:	00001	00050	// if not, input string is Not accepted
025:	00006		// if yes, read next input symbol
026:	00026	00015	// store input symbol to Var address
030:	00040	00013	// does input symbol equal to acceptable 'b' ?
032:	00001	00036	// if not, does it equal to terminating symbol '#' ?
034:	00002	00025	// if yes, 'b' is accepted and next input symbol should be read
036:	00020	00015	// reload symbol from Var
040:	00040	00014	// does input symbol equal to terminating symbol '#' ?
042:	00001	00050	// if not, jump to 'input string is Not accepted'
044:	00021	00101	// if yes, input string is accepted, so load indication 'A'
046:	00011		// output 'A' indicating input string is accepted
047:	00005		// stop finite state automaton
050:	00021	00116	// since input string is not accepted, load indication 'N'
052:	00011		// output 'N' indicating input string is not accepted
053:	00005		// stop finite state automaton

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